



# RESEARCH MEMORANDUM

LIFT, DRAG, AND PITCHING MOMENT OF LOW-ASPECT-RATIO

WINGS AT SUBSONIC AND SUPERSONIC SPEEDS -

PLANE TRIANGULAR WING OF ASPECT RATIO 4

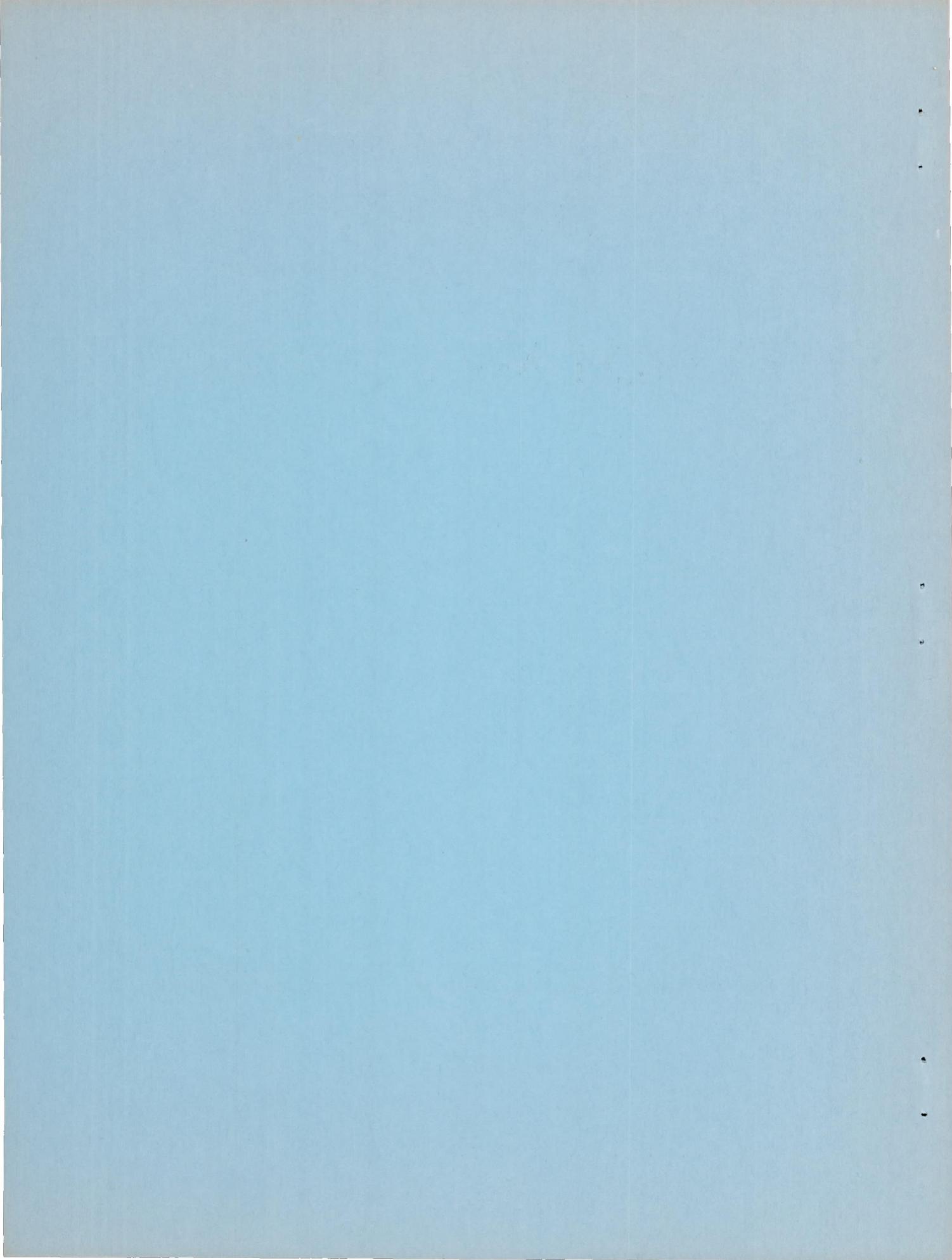
WITH 3-PERCENT-THICK, BICONVEX SECTION

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NATIONAL ADVISORY COMMITTEE  
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## NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUMLIFT, DRAG, AND PITCHING MOMENT OF LOW-ASPECT-RATIO  
WINGS AT SUBSONIC AND SUPERSONIC SPEEDS -  
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## SUMMARY

A wing-body combination having a plane triangular wing of aspect ratio 4 and 3-percent-thick, biconvex sections in streamwise planes has been investigated at both subsonic and supersonic Mach numbers. The lift, drag, and pitching moment of the model are presented for Mach numbers from 0.60 to 0.92 and from 1.20 to 1.70 at Reynolds numbers of 1.66 million, 2.91 million, and 4.15 million. (The maximum Mach number was limited to 1.60 at the highest Reynolds number.)

## INTRODUCTION

A research program is in progress at the Ames Aeronautical Laboratory to ascertain experimentally at subsonic and supersonic Mach numbers the characteristics of wings of interest in the design of high-speed fighter airplanes. The effects of variations in plan form, twist, camber, and thickness are being investigated. This report is one of a series pertaining to this program and presents results of tests of a wing-body combination having a plane triangular wing of aspect ratio 4 and 3-percent-thick, biconvex sections in streamwise planes. Results of other investigations in this program are presented in references 1 to 8. As in these references, the data herein are presented without analysis to expedite publication.

## NOTATION

$b$	wing span
$\bar{c}$	mean aerodynamic chord $\left( \frac{\int_0^{b/2} c^2 dy}{\int_0^{b/2} c dy} \right)$
$c$	local wing chord
$l$	length of body including portion removed to accommodate sting
$\frac{L}{D}$	lift-drag ratio
$\left( \frac{L}{D} \right)_{max}$	maximum lift-drag ratio
$M$	Mach number
$q$	free-stream dynamic pressure
$R$	Reynolds number based on the mean aerodynamic chord
$r$	radius of body
$r_0$	maximum body radius
$S$	total wing area, including area formed by extending leading and trailing edges to plane of symmetry
$x$	longitudinal distance from nose of body
$y$	distance perpendicular to plane of symmetry
$\alpha$	angle of attack of body axis, degrees
$C_D$	drag coefficient $\left( \frac{\text{drag}}{qS} \right)$
$C_L$	lift coefficient $\left( \frac{\text{lift}}{qS} \right)$
$C_m$	pitching-moment coefficient referred to quarter point of mean aerodynamic chord $\left( \frac{\text{pitching moment}}{qS_c} \right)$
$\frac{dC_L}{d\alpha}$	slope of the lift curve measured at zero lift, per degree
$\frac{dC_m}{dC_L}$	slope of the pitching-moment curve measured at zero lift

## APPARATUS

## Wind Tunnel and Equipment

The experimental investigation was conducted in the Ames 6- by 6-foot supersonic wind tunnel. In this wind tunnel, the Mach number can be varied continuously and the stagnation pressure can be regulated to maintain a given test Reynolds number. The air is dried to prevent formation of condensation shocks. Further information on this wind tunnel is presented in reference 9.

The model was sting-mounted in the tunnel, the diameter of the sting being about 82 percent of the diameter of the body base. The pitch plane of the model support was horizontal. A 4-inch diameter, four-component, strain-gage balance, described in reference 10, enclosed within the body of the model, was used to measure the aerodynamic forces and moments.

## Model

A photograph of the model mounted in the Ames 6- by 6-foot wind tunnel is shown in figure 1. A plan and a front view of the model and certain model dimensions are given in figure 2. Other important geometric characteristics of the model are as follows:

## Wing

Aspect ratio . . . . .	4
Taper ratio. . . . .	0
Airfoil section (streamwise) . . .	3-percent thick, biconvex
Total area, $S$ , square feet . . . . .	2.425
Mean aerodynamic chord, $\bar{c}$ , feet. . . . .	1.038
Dihedral, degrees . . . . .	0
Camber . . . . .	None
Twist, degrees . . . . .	0
Incidence, degrees . . . . .	0
Distance, wing-chord plane to body axis, feet . . . . .	0

## Body

Fineness ratio (based upon length $l$ ; fig. 2) . . . . .	12.5
Cross-section shape . . . . .	Circular
Maximum cross-sectional area, square feet . . . . .	0.1235
Ratio of maximum cross-sectional area to wing area . . .	0.0509

The wing was constructed of solid steel. The body spar was also steel and was covered with aluminum to form the body contours. The surfaces of the wing and body were polished smooth.

#### TESTS AND PROCEDURE

##### Range of Test Variables

The aerodynamic characteristics of the model (as a function of angle of attack) were investigated for a range of Mach numbers from 0.60 to 0.92 and from 1.20 to 1.70. The major portion of the data was obtained at Reynolds numbers of 1.66 million and 2.91 million. Data were also obtained for a Reynolds number of 4.15 million at Mach numbers up to 1.60.

##### Reduction of Data

The test data have been reduced to standard NACA coefficient form. Factors which could affect the accuracy of these results, together with the corrections applied, are discussed in the following paragraphs.

Tunnel-wall interference.— Corrections to the subsonic results for the induced effects of the tunnel walls resulting from lift on the model were made according to the methods of reference 11. The numerical values of these corrections (which were added to the uncorrected data) were obtained from

$$\Delta\alpha = 0.592 C_L$$

$$\Delta C_D = 0.01035 C_L^2$$

No corrections were made to the pitching-moment coefficients.

The effects of constriction of the flow at subsonic speeds by the tunnel walls were taken into account by the method of reference 12. This correction was calculated for conditions at zero angle of attack and was applied throughout the angle-of-attack range. At a Mach number of 0.90, this correction amounted to a 2-percent increase in the Mach number and in the dynamic pressure over that determined from a calibration of the wind tunnel without a model in place.

For the tests at supersonic speeds, the reflection from the tunnel walls of the Mach wave originating at the nose of the body did not cross the model. No corrections were required, therefore, for tunnel-wall effects.

Stream variations.— Tests at subsonic speed of the present symmetrical model in both the normal and the inverted positions have indicated a slight stream curvature and inclination in the pitch plane of the model. Results of these tests indicate that a  $-0.05^{\circ}$  stream inclination and a stream curvature capable of producing a pitching-moment coefficient of  $-0.004$  at zero lift exist throughout the subsonic Mach number range. No corrections were made to the data of the present report for the effect of these stream irregularities. No measurements have been made, however, of the stream curvature in the yaw plane. At subsonic speeds, the longitudinal variation of static pressure in the region of the model is not known accurately at present, but a preliminary survey has indicated that it is less than 2 percent of the dynamic pressure. No correction for this effect was made.

A survey of the air stream in the 6- by 6-foot wind tunnel at supersonic speeds (reference 9) has shown a stream curvature only in the yaw plane of the model. The effects of this curvature on the measured characteristics of the present model are not known, but are believed to be small as judged by the results of reference 13. The survey of reference 9 also indicated that there is a static-pressure variation in the test section of sufficient magnitude to affect the drag results. A correction was added to the measured drag coefficient, therefore, to account for the longitudinal buoyancy caused by this static-pressure variation. This correction varied from as much as  $-0.0008$  at a Mach number of 1.30 to 0.0006 at a Mach number of 1.70.

Support interference.— At subsonic speeds, the effects of support interference on the aerodynamic characteristics of the model are not known. For the present tailless model, it is believed that such effects consisted primarily of a change in the pressure at the base of the model. In an effort to correct at least partially for this support interference, the base pressure was measured and the drag data were adjusted to correspond to a base pressure equal to the static pressure of the free stream.

At supersonic speeds, the effects of support interference of a body-sting configuration similar to that of the present model are shown by reference 14 to be confined to a change in base pressure. The previously mentioned adjustment of the drag for base pressure, therefore, was applied at supersonic speeds.

## RESULTS

The variation of lift coefficient with angle of attack and the variations of pitching-moment coefficient, drag coefficient, and lift-drag ratio with lift coefficient at Mach numbers from 0.60 to 1.70 and

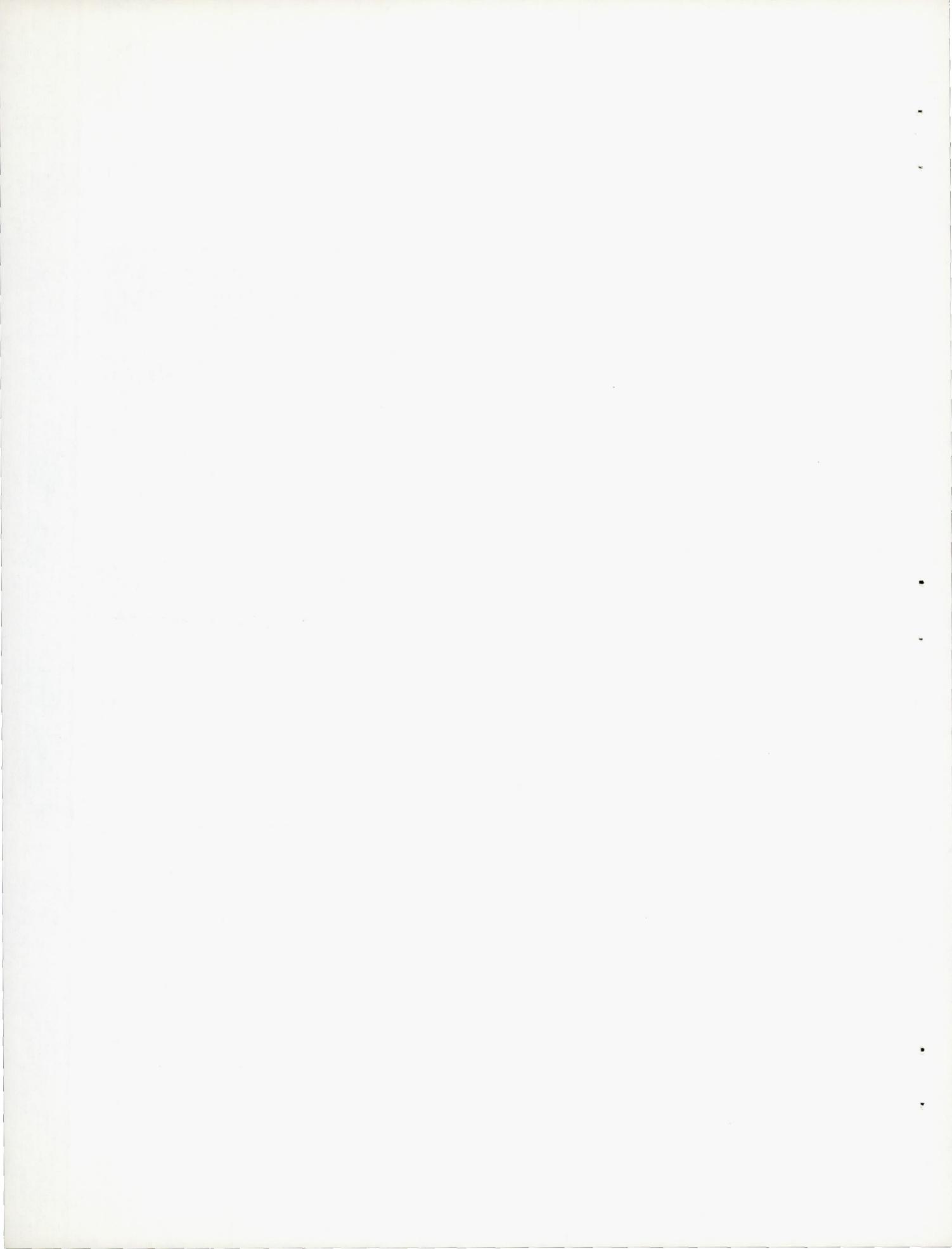
at Reynolds numbers of 1.66 million and 2.91 million are shown in figures 3 and 4, respectively. Similar characteristics are shown in figure 5 for Mach numbers from 0.60 to 1.60 at a Reynolds number of 4.15 million. The results presented in figure 4 have been summarized in figure 6 to show some important parameters as functions of Mach number. The slope parameters in this figure have been measured at zero lift.

Ames Aeronautical Laboratory,  
National Advisory Committee for Aeronautics,  
Moffett Field, Calif.

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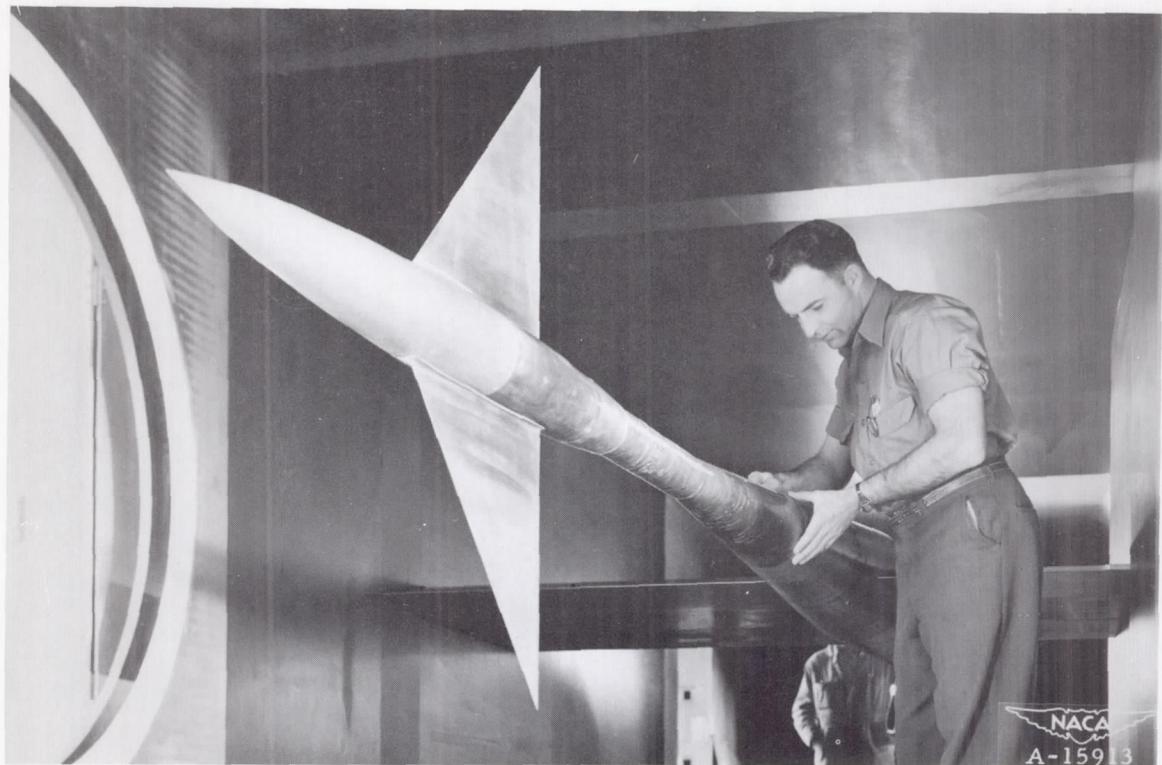
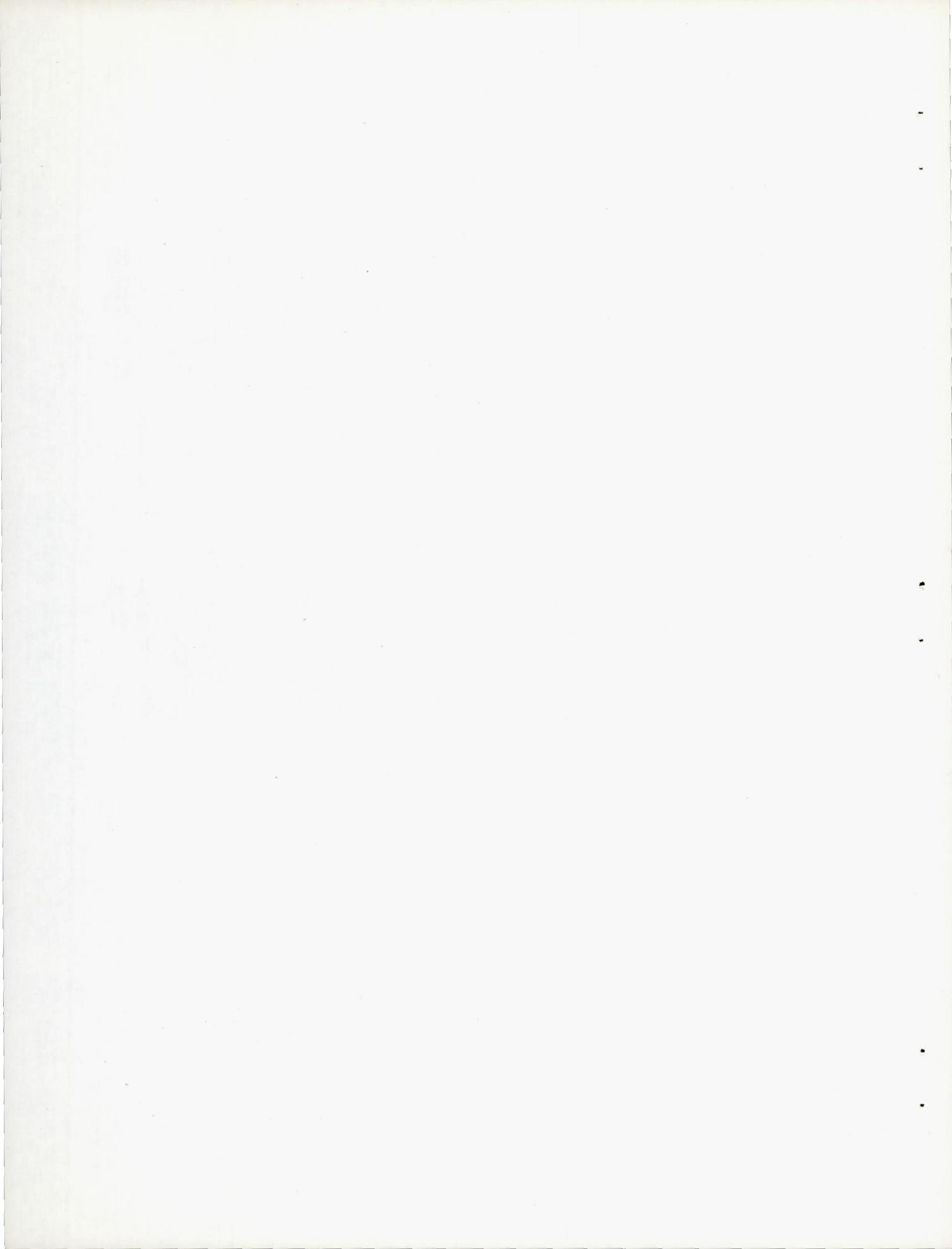


Figure 1.—Model in the Ames 6- by 6-foot supersonic wind tunnel.



*Equation of fuselage radii*

$$\frac{r}{t_0} = \left[ l - \left( l - \frac{2x}{l} \right)^{2/3} \right]$$

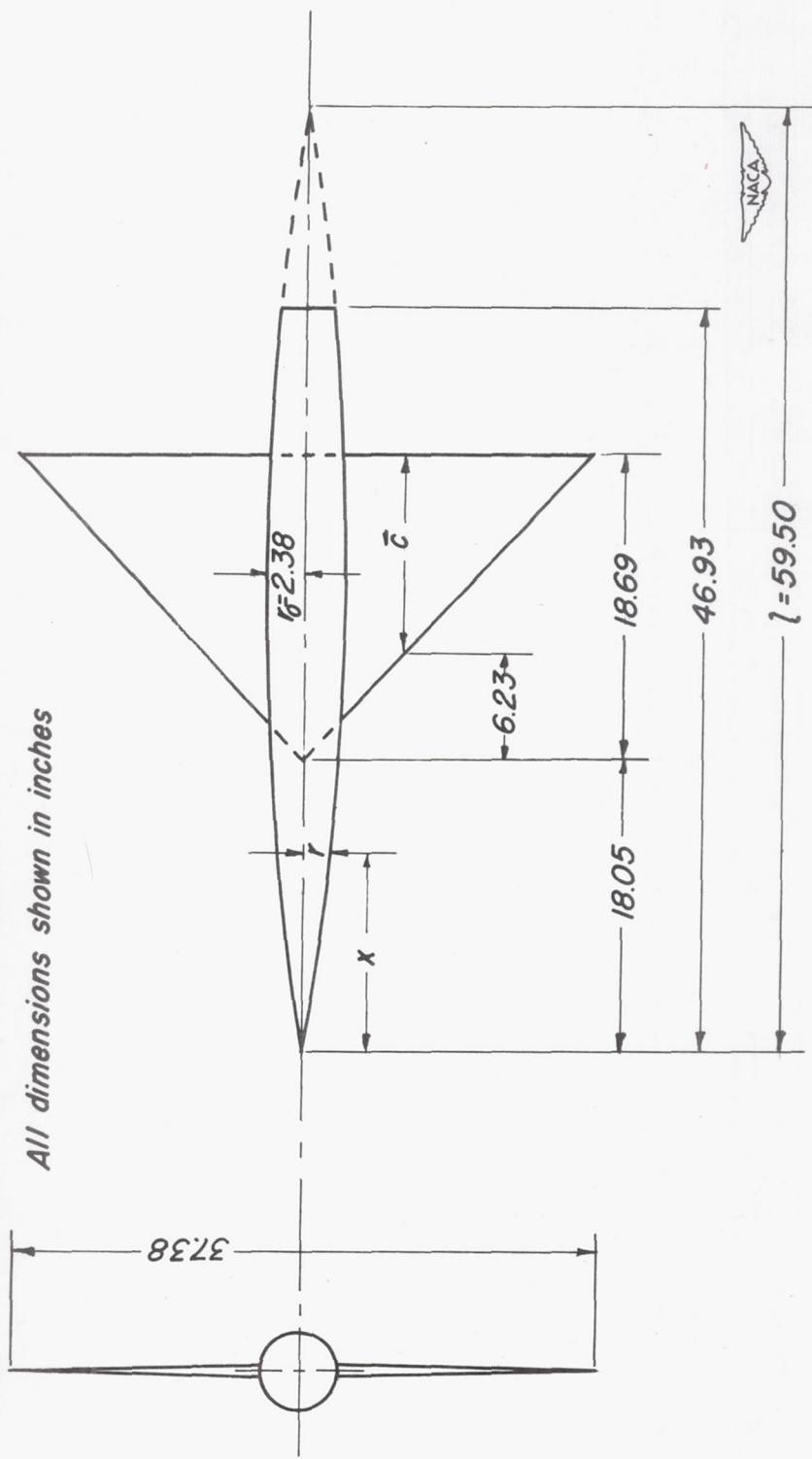


Figure 2.—Front and plan views of the model.

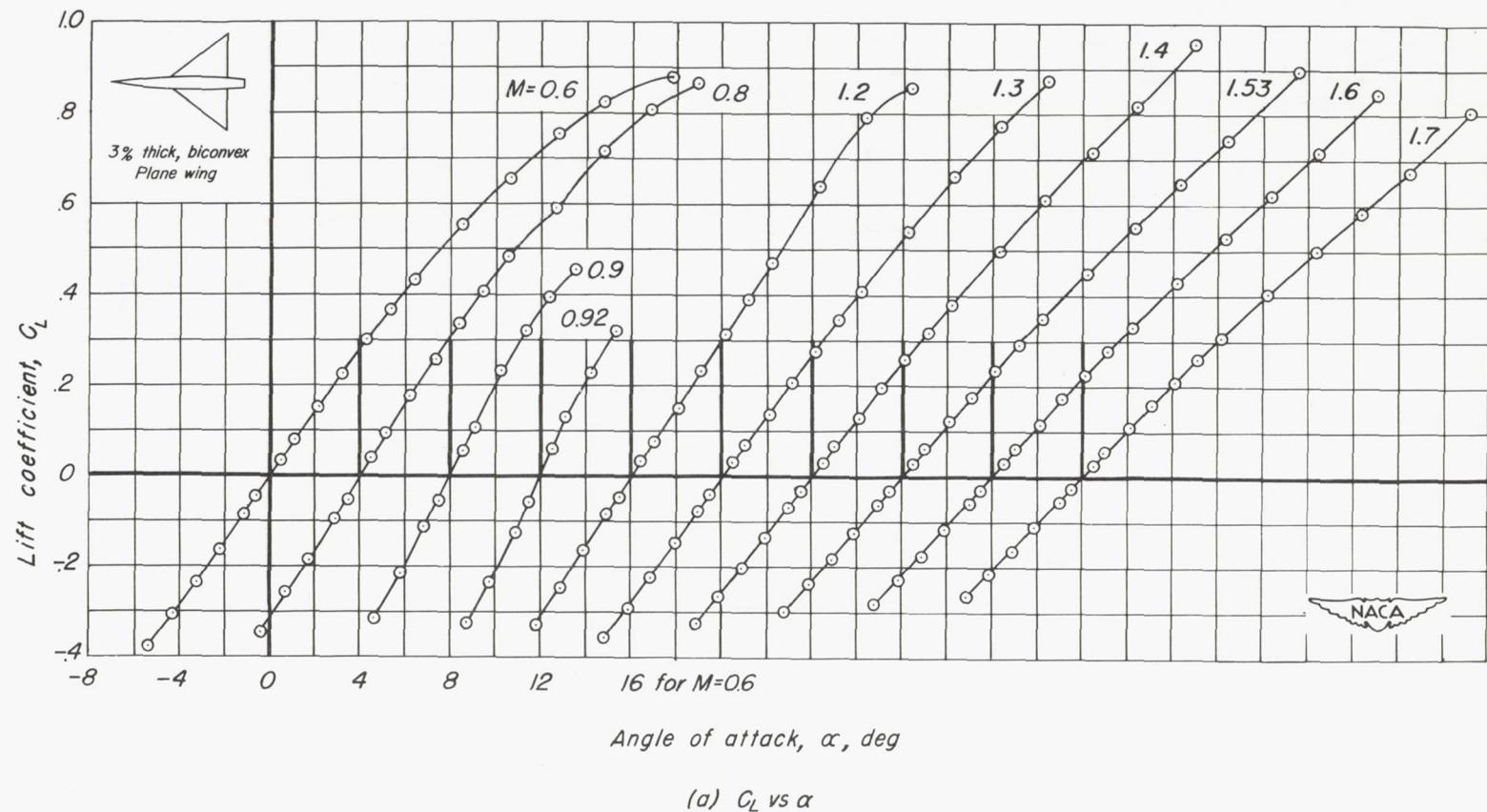


Figure 3.—The variation of the aerodynamic characteristics with lift coefficient at various Mach numbers.  
 $R, 1.66\text{ million.}$

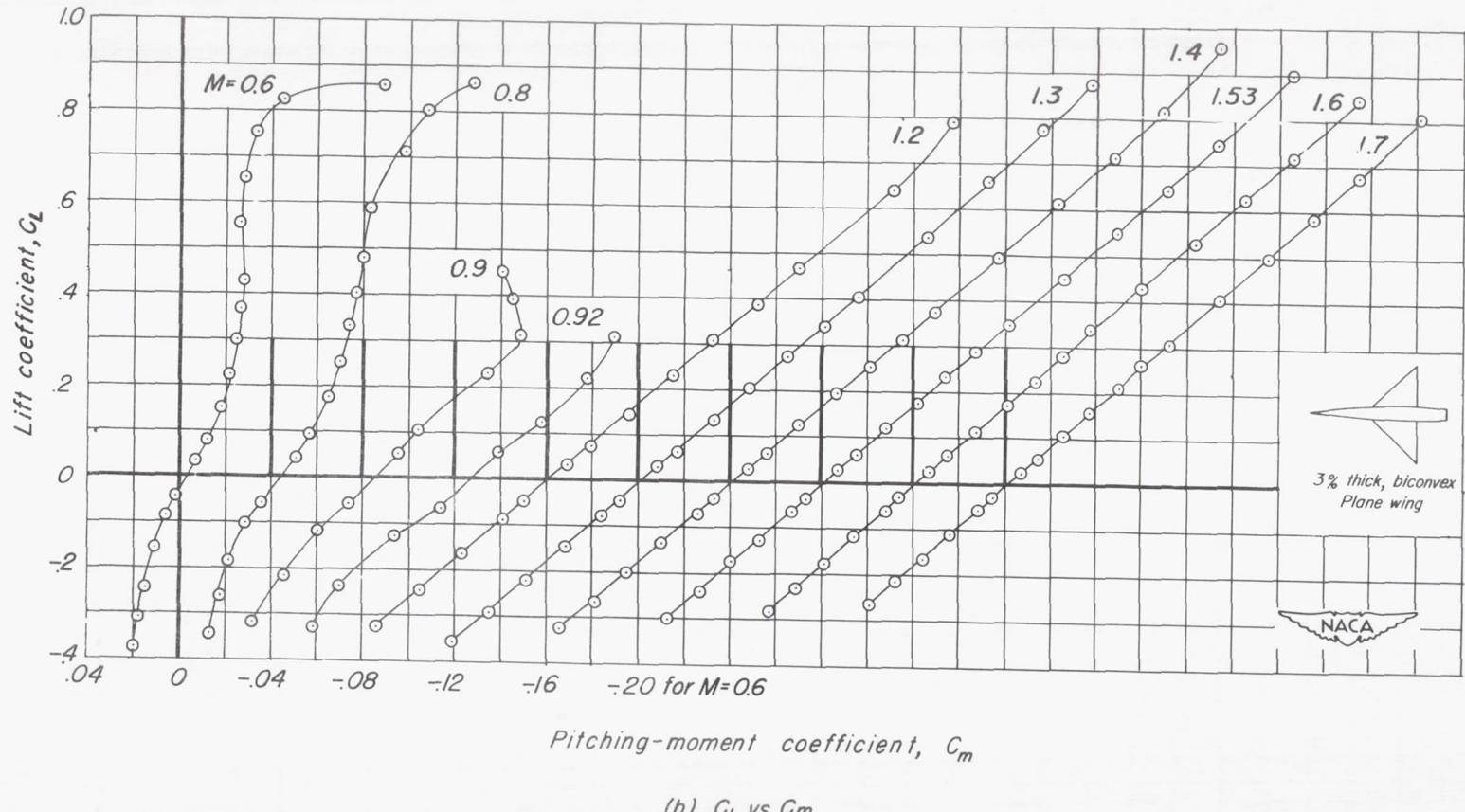


Figure 3. - Continued.

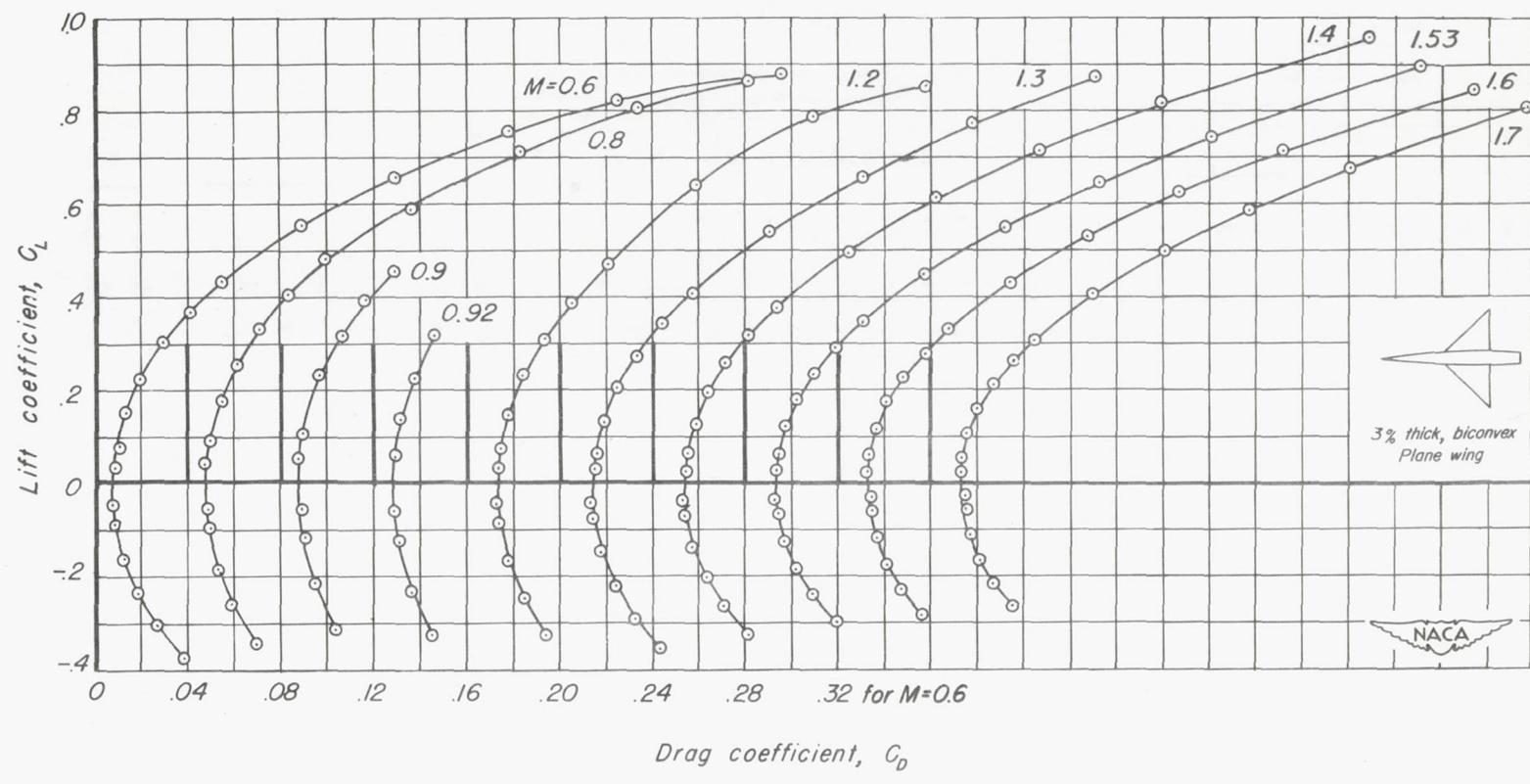
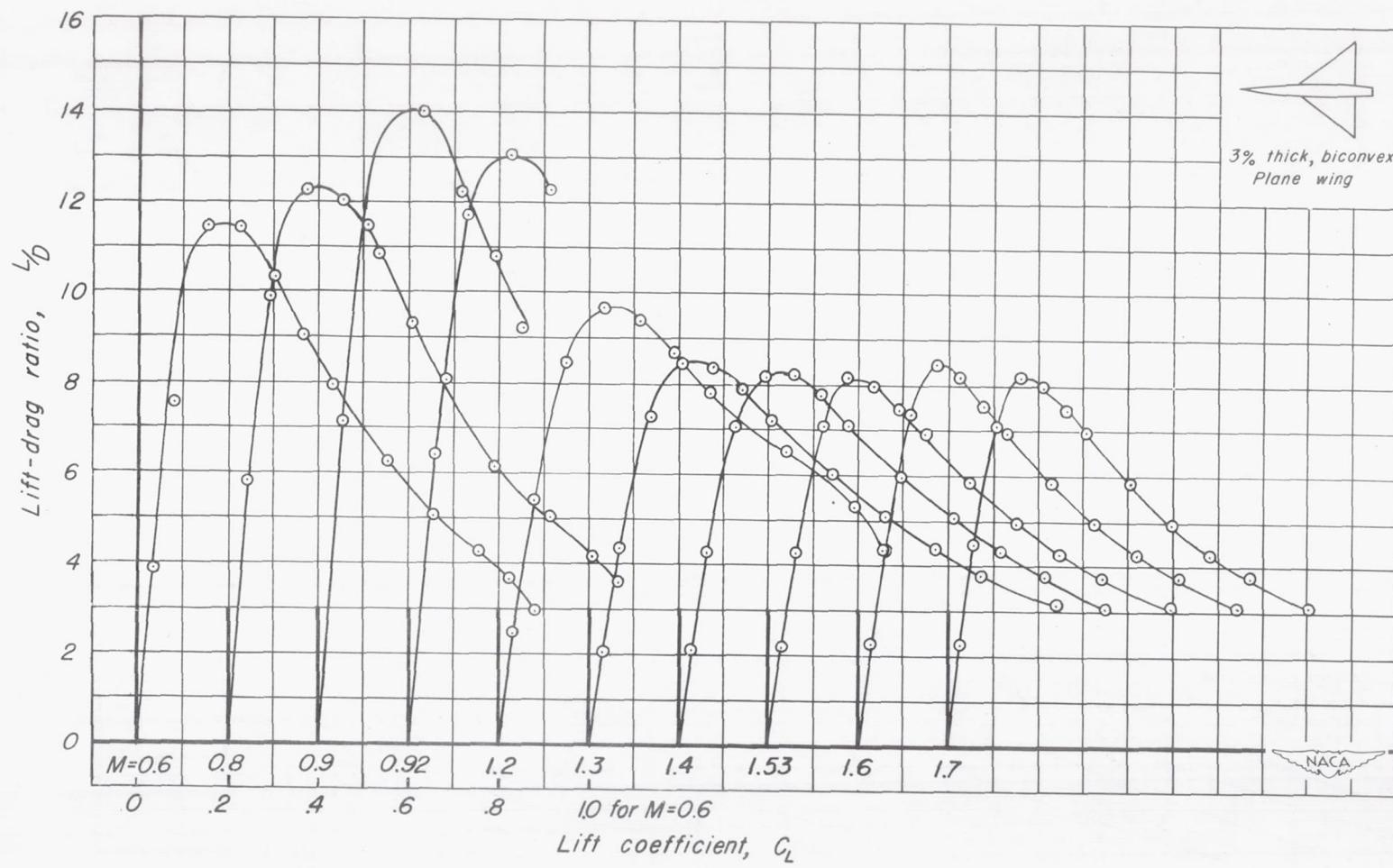
(c)  $C_L$  vs  $C_D$ 

Figure 3-Continued.



(d)  $L_D$  vs  $C_L$   
Figure 3.-Concluded.

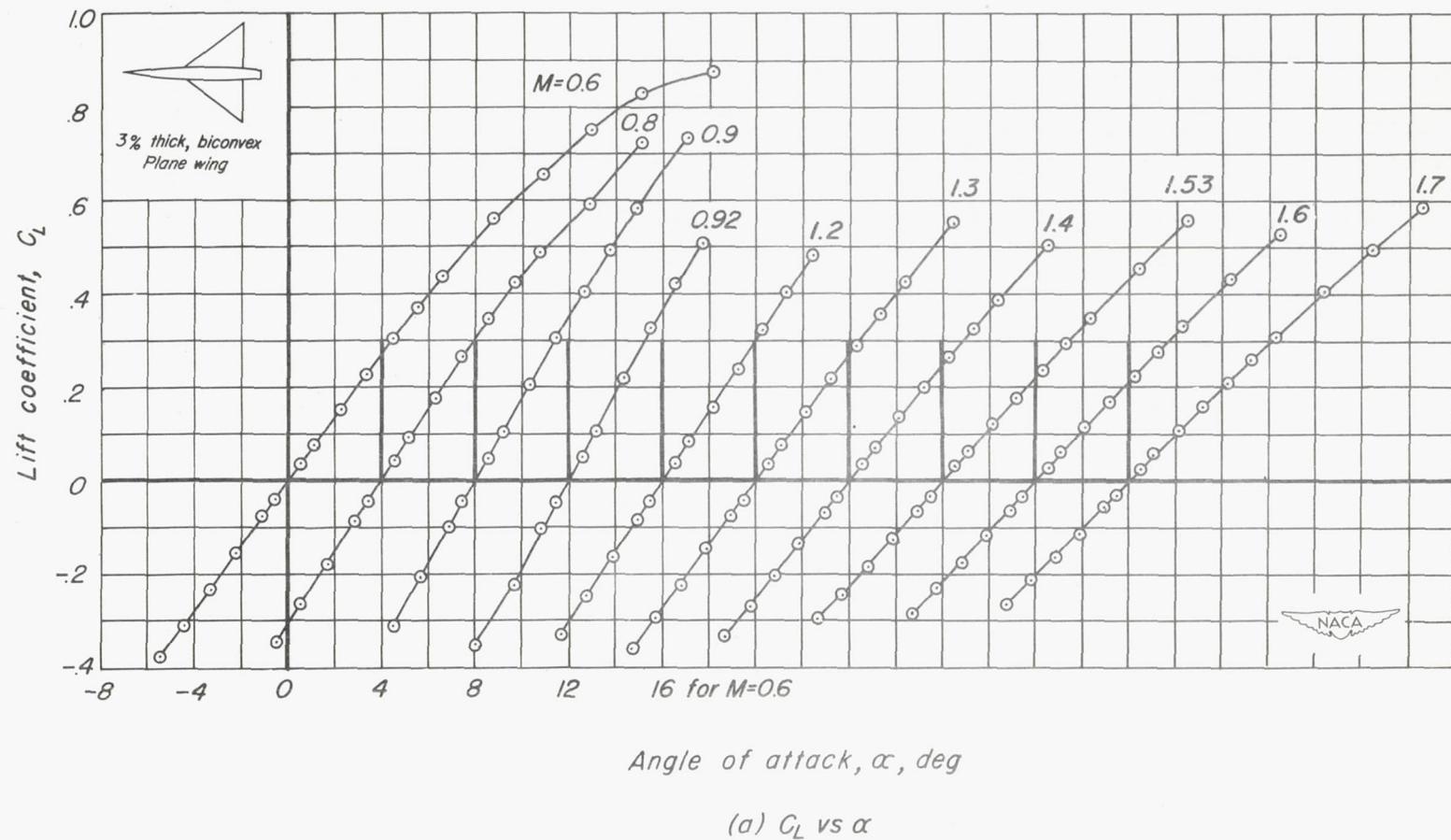


Figure 4.—The variation of the aerodynamic characteristics with lift coefficient at various Mach numbers.  
 $R, 2.91 \text{ million.}$

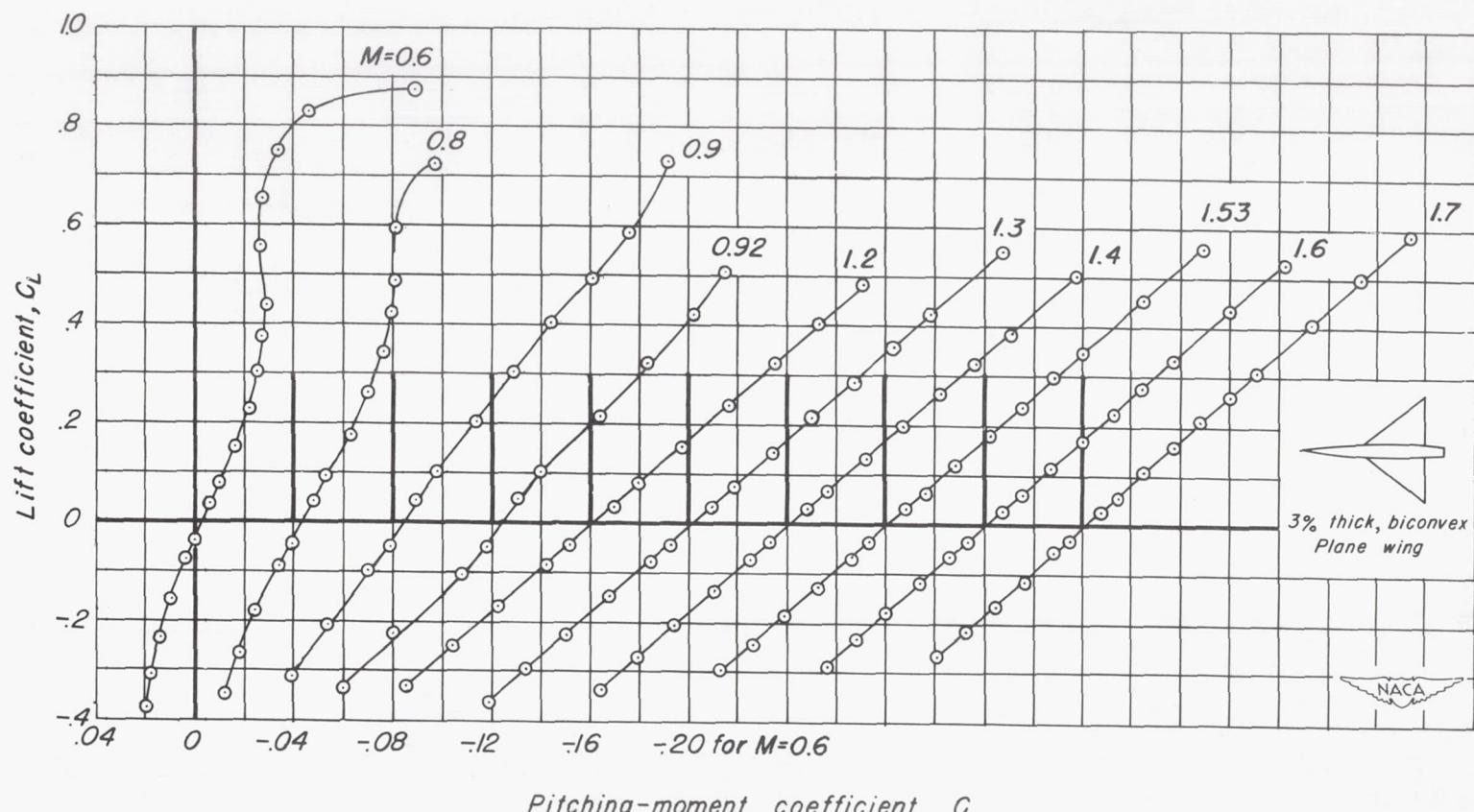
(b)  $C_L$  vs  $C_m$ 

Figure 4.—Continued.

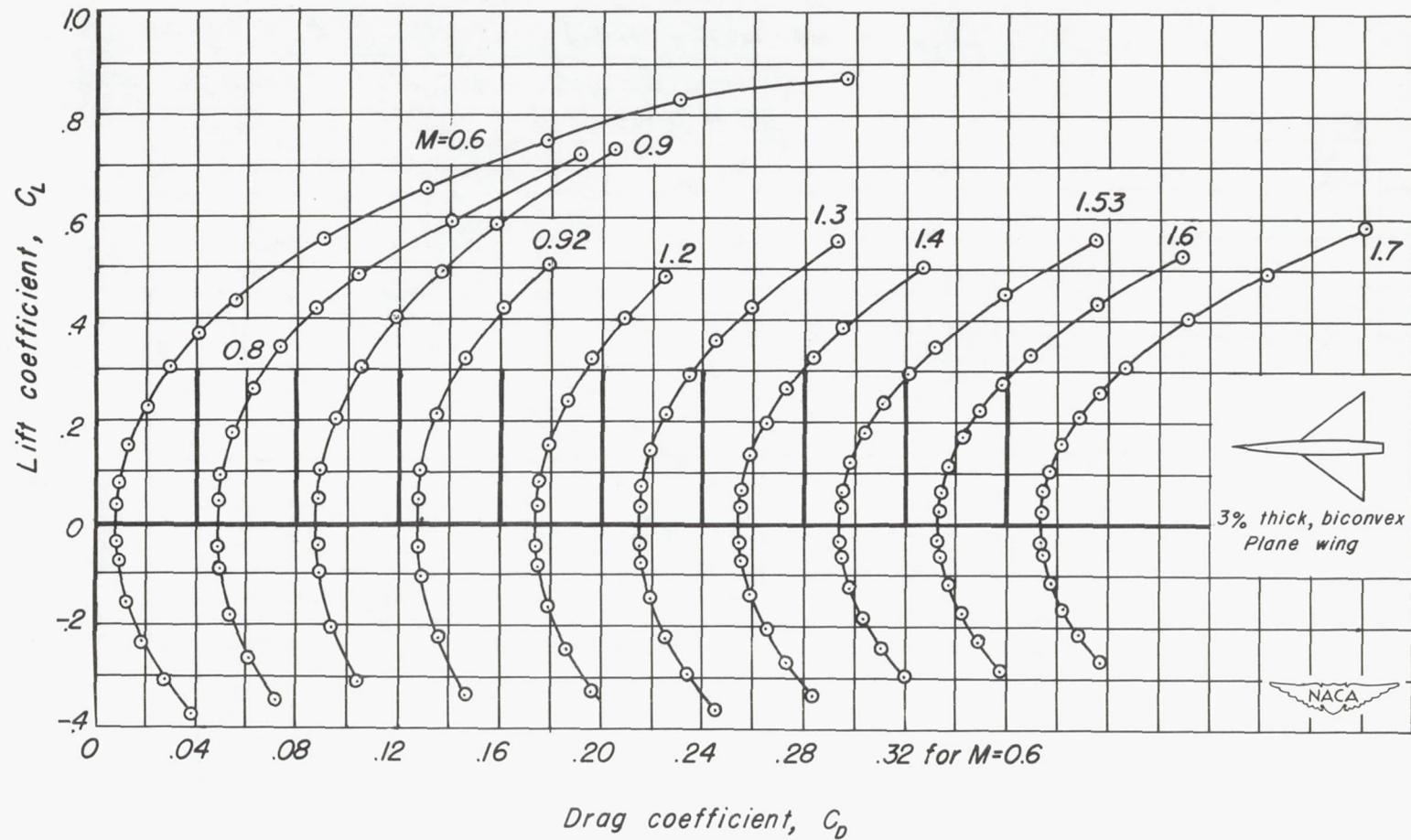


Figure 4.-Continued.

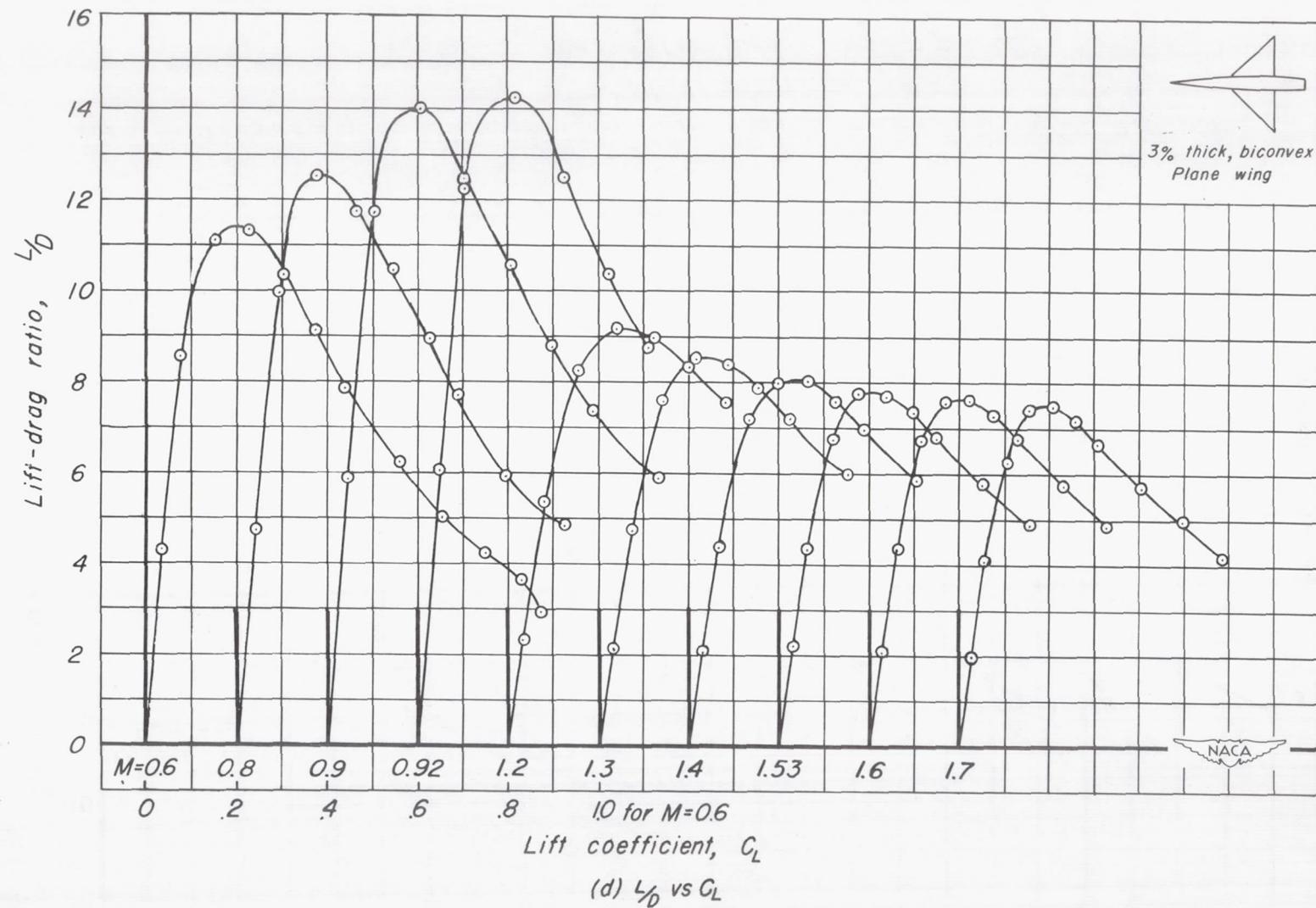
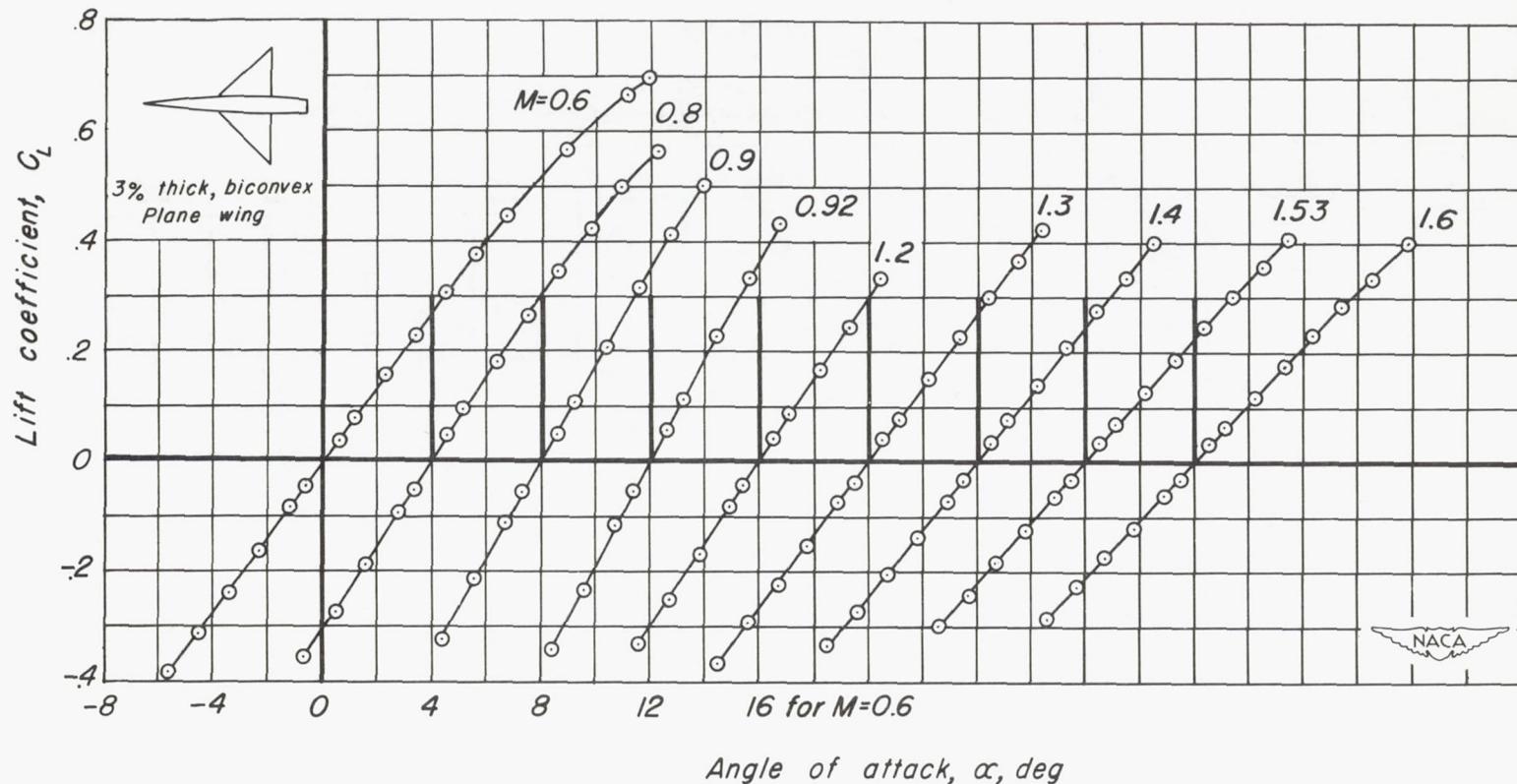


Figure 4.-Concluded.



(a)  $C_L$  vs  $\alpha$

Figure 5.—The variation of the aerodynamic characteristics with lift coefficient at various Mach numbers.  
 $R, 4.15\text{ million}$ .

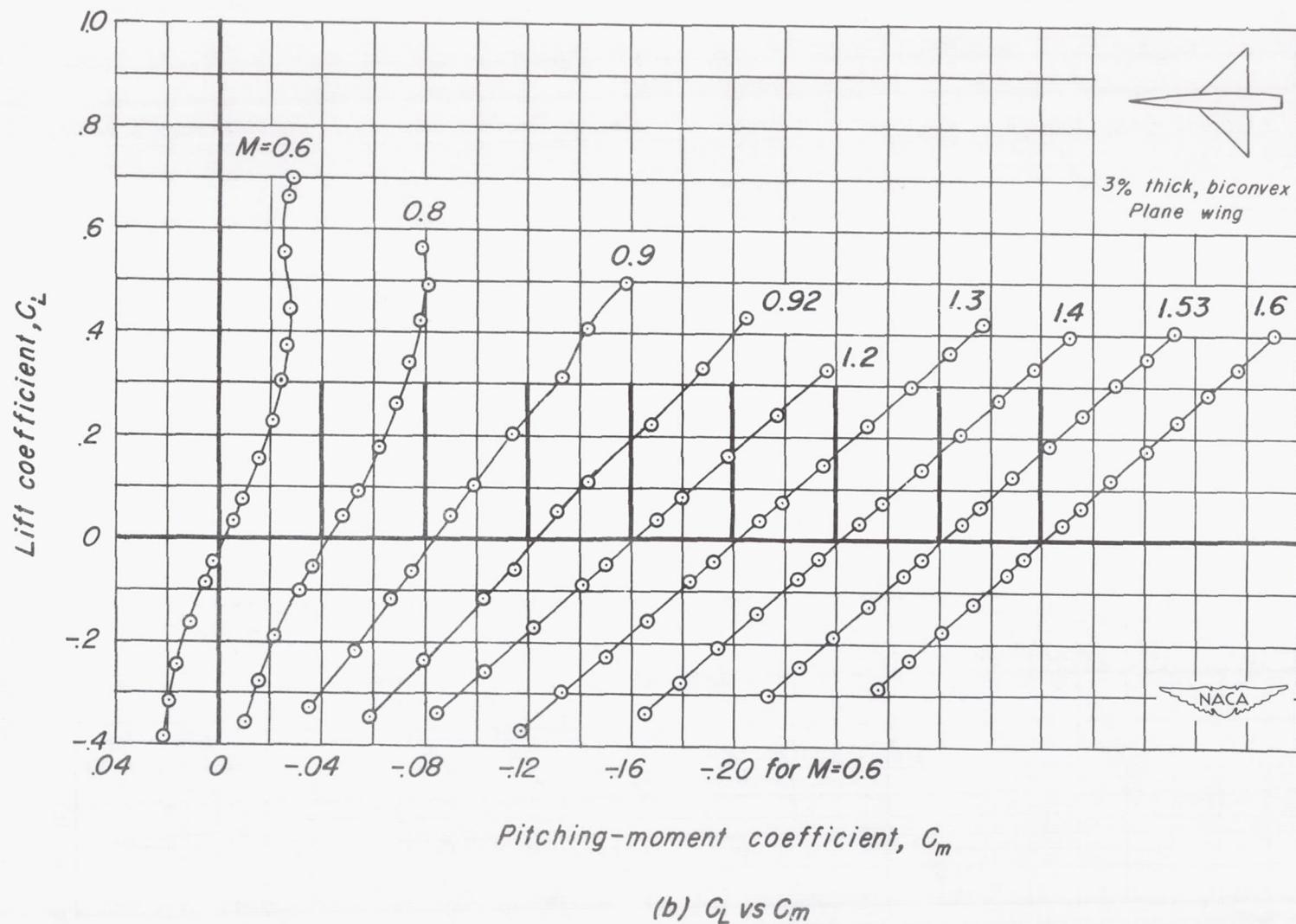
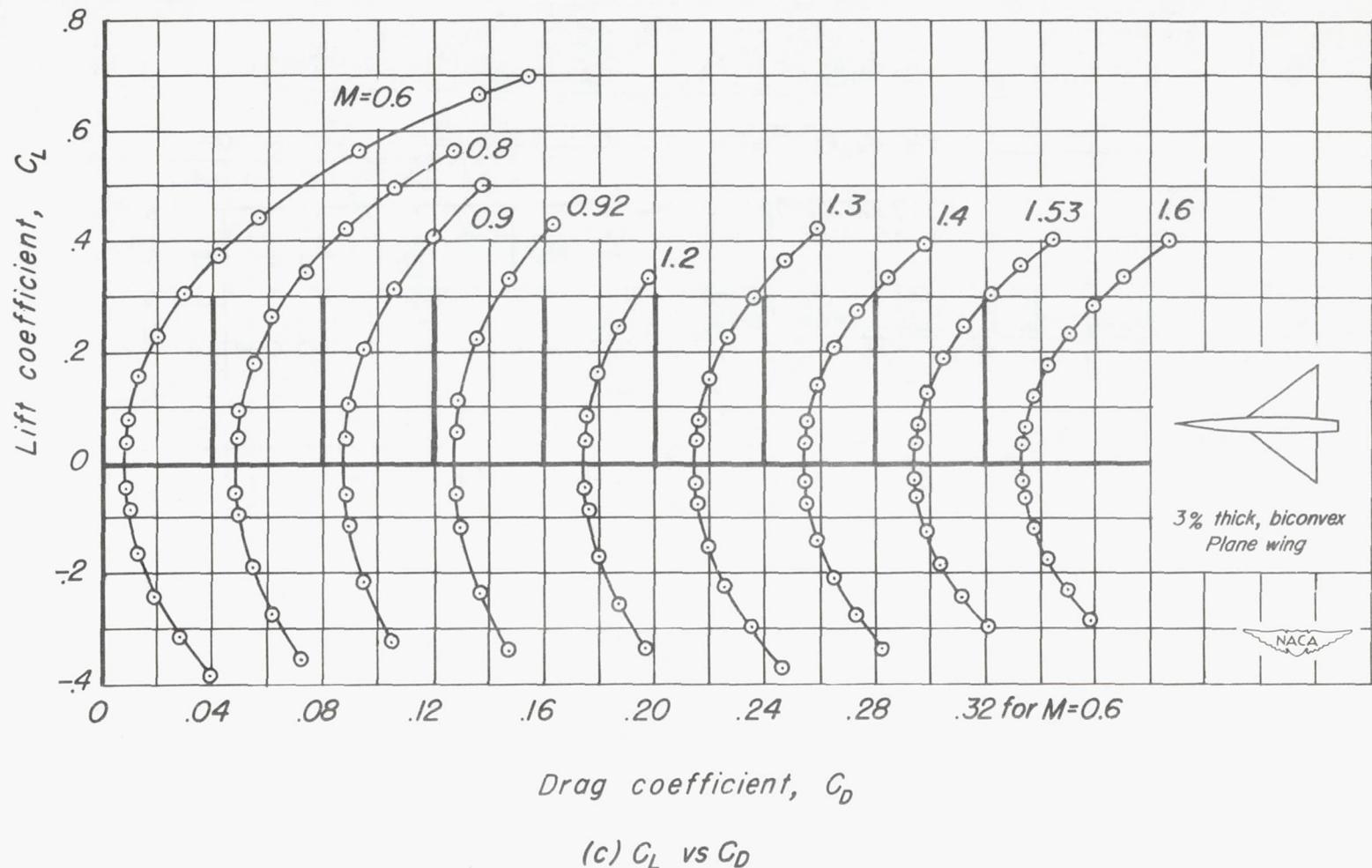


Figure 5.-Continued.



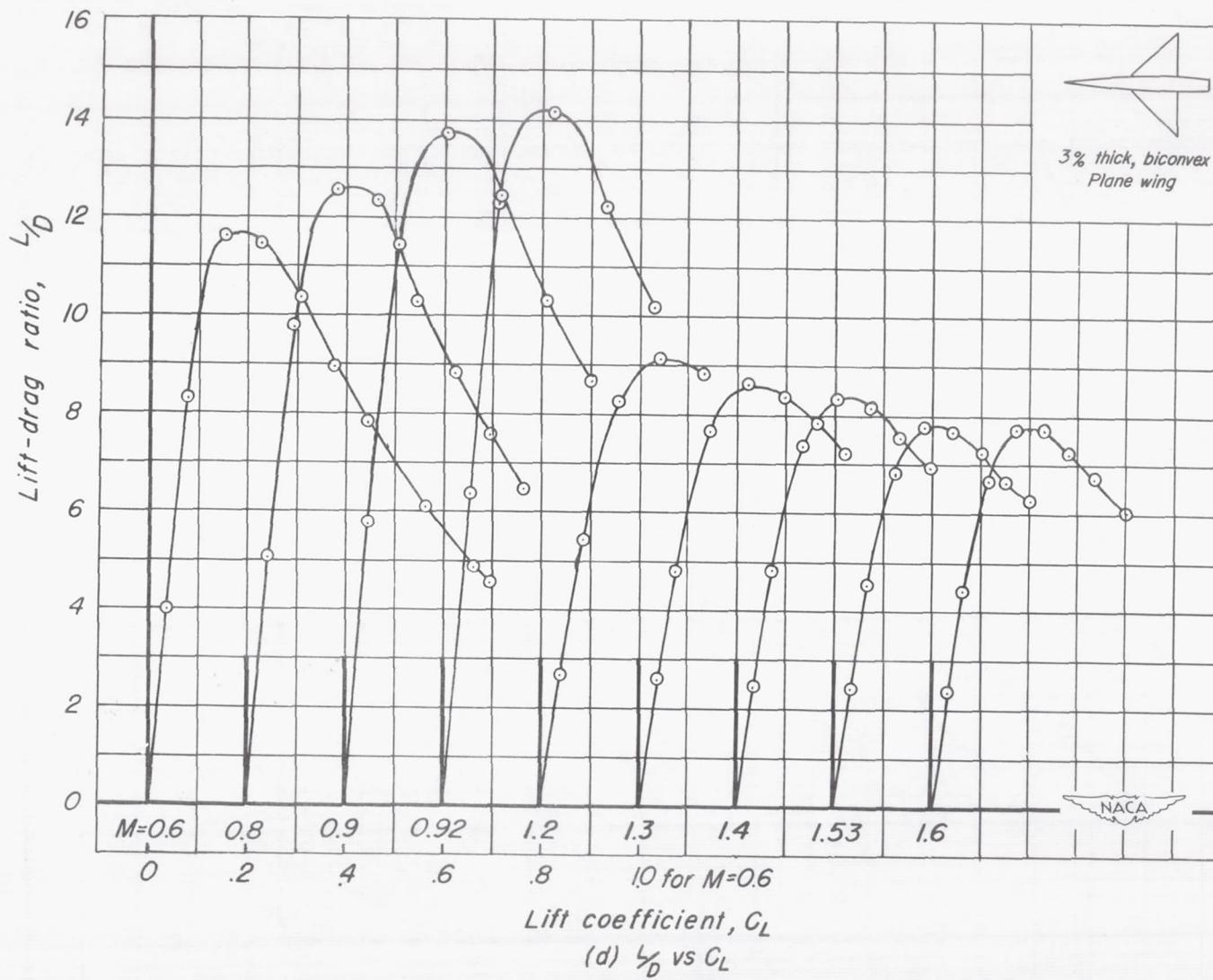
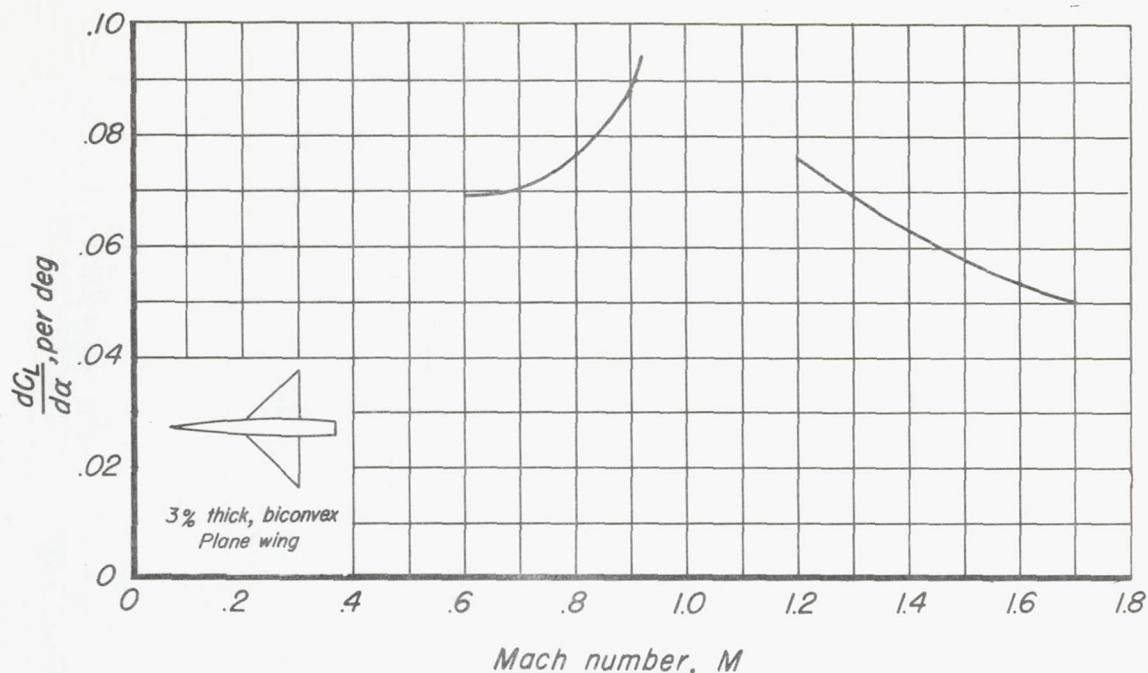
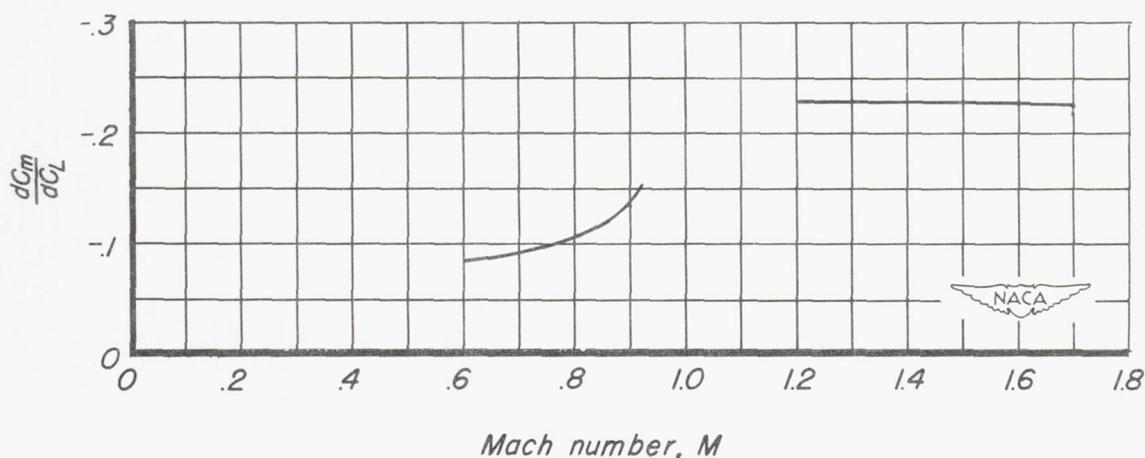


Figure 5.- Concluded.



$$(a) \frac{dC_L}{d\alpha} \text{ vs } M$$



$$(b) \frac{dC_m}{dC_L} \text{ vs } M$$

Figure 6.-Summary of aerodynamic characteristics as a function of Mach number.  $R$ , 2.91 million

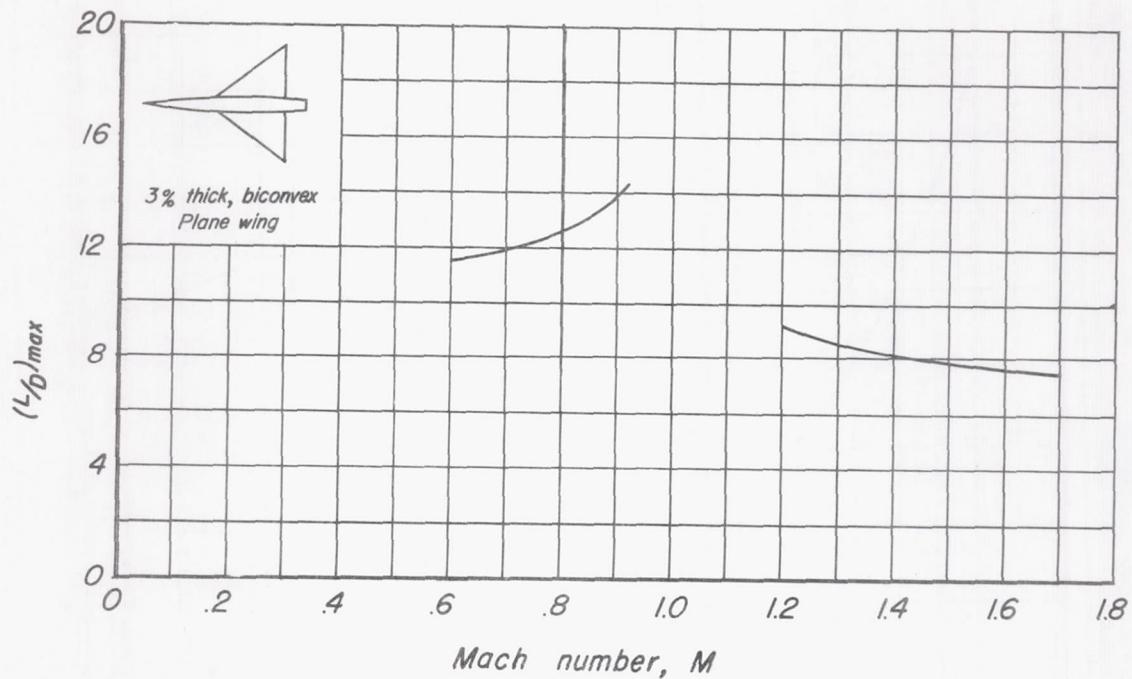
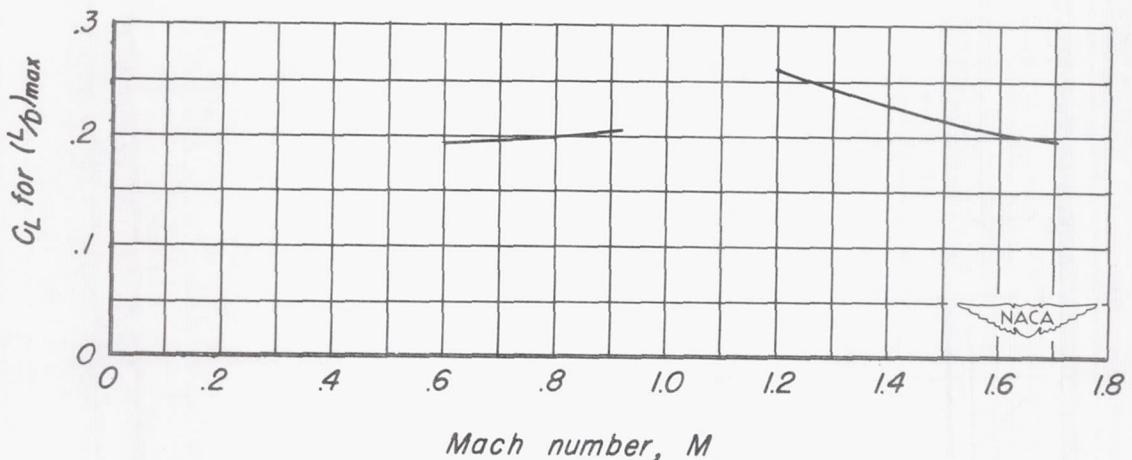
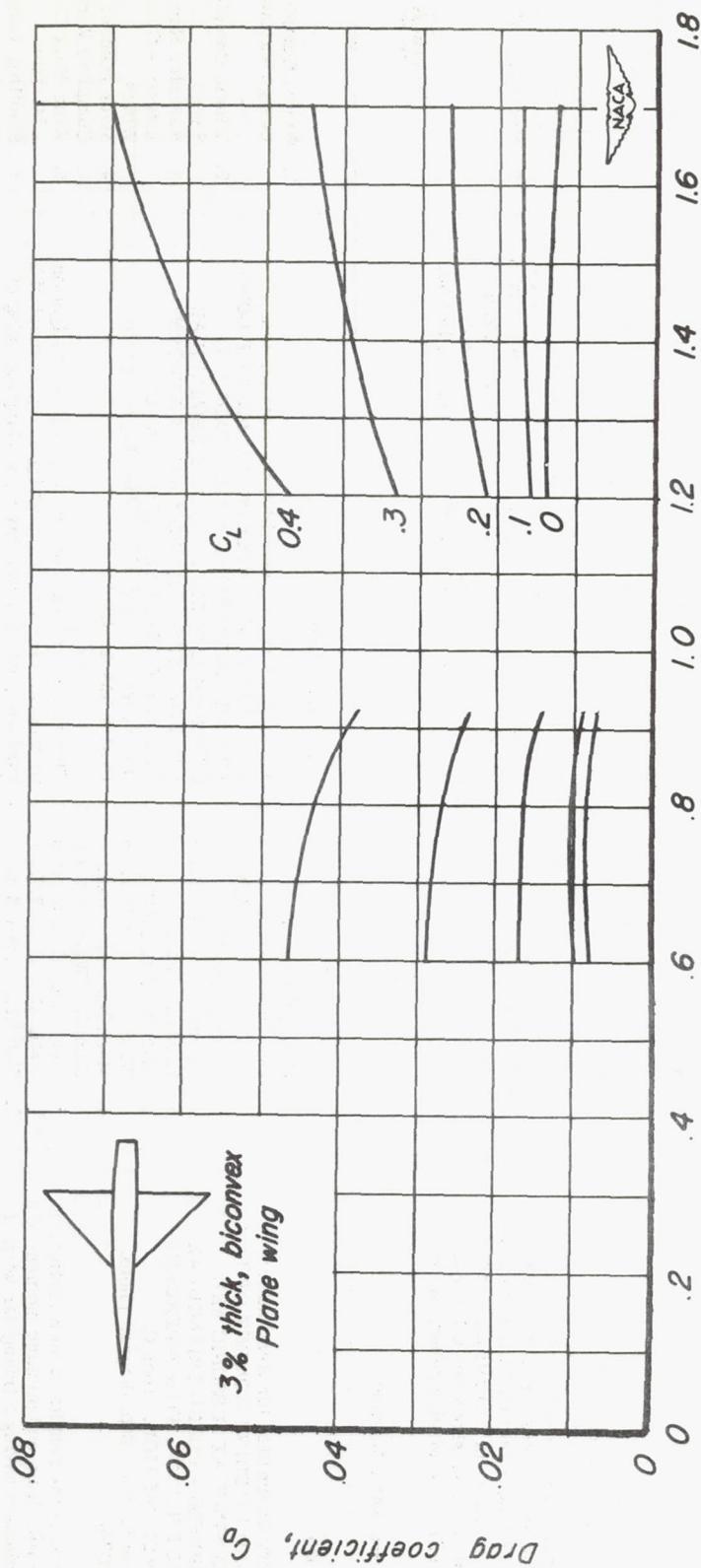
(c)  $(L/D)_{max}$  vs  $M$ (d)  $C_L$  for  $(L/D)_{max}$  vs  $M$ 

Figure 6.-Continued.



Mach number,  $M$

(e)  $C_d$  vs  $M$

Figure 6.-Concluded.